Glass

fives ultimate machines ultimate factory

All-electric Melting Technology

(and application to Container Glass)

GLASSMAN ASIA 2019
30-31 January, Jakarta, Indonesia

January 2019
andy.reynolds@fivesgroup.com

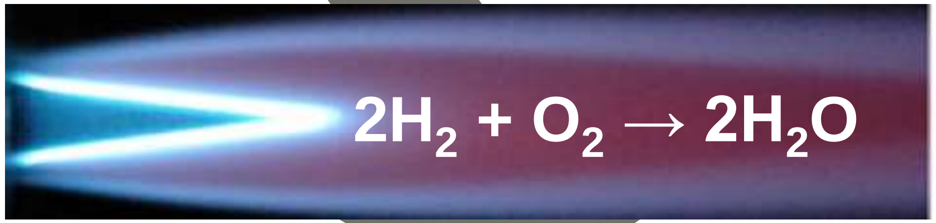
All-electric Melting Technology

All-electric Melting (Alternative Technologies)

fives

INDIRECT USE OF ELECTRICITY

e.g. $2H_2O \rightarrow 2H_2 + O_2$

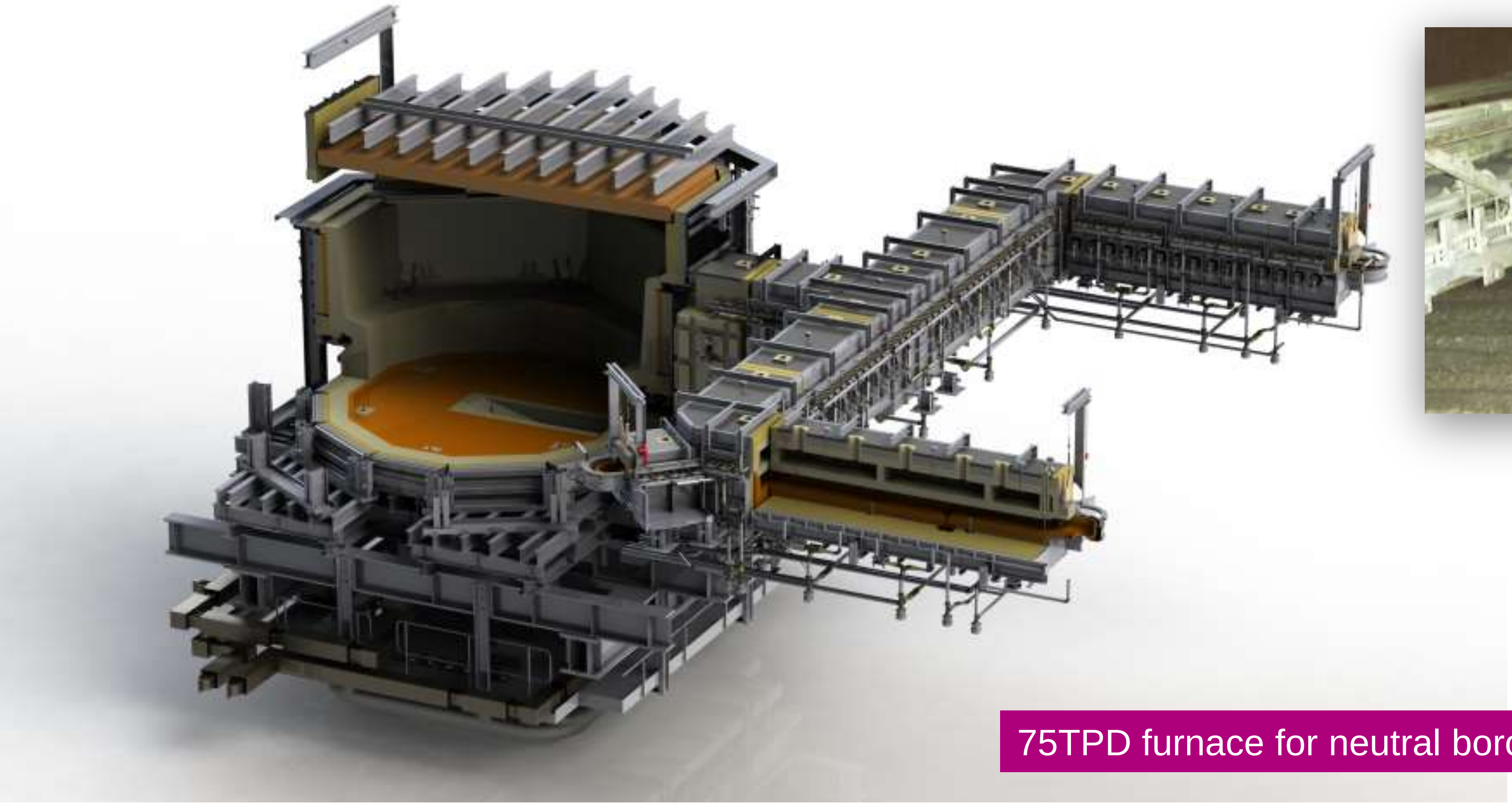


DIRECT ELECTRIC HEATING

Resistive, Induction, Radiative, Microwave

All-electric Melting Technology

Cold-top Vertical Melter (CTVM)



75TPD furnace for neutral borosilicate

All-electric Melting Technology

Applications

All-electric CTVM melting is already successfully applied to many (most) type of glass and at various capacities

Bottles (high volume/low $)

Container

Tableware

Crystalline/Crystal

Perfumery and Cosmetics

Drawn fibre (E, ECR, Silica)

Coloured glasses (float/rolled)

Opal Glass

HV Insulators

Cover Glass

Tubing (Neutral Borosilicate)

Spun fibre (C Glass)

All-electric Melting Technology

Applications

- All-electric (resistive) melting generally implies cold-top vertical melting (CTVM)
- CTVM formats have been applied successfully to many (most) type of glass
- Furnaces capacities limited by production requirements (not technology) normally **10 - 100 TPD**
- Larger capacities for fibre and insulation products are common
- A few larger container furnaces have been built (~200-250TPD)
- At least one mini-float all-electric furnace has been built to date.

60m2 (120 TPD) CTVM furnace for (mini) float

All-electric Melting Technology

Electric Melting Today

BORMIOLI LUIGI
GLASSMAKER

Fives State-of-the Art technology
$40m^2$ 80-90TPD (cosmetic glass)
Target performance:
- <900kWh/tonne at 7-8 year life

System features:
- Integrated cooling-air,
- low maintenance electrode configuration

Electric Melting Furnace Overview

The FURNACE is designed to melt low iron SODA LIME GLASS compostion at an average rate of 50 to 100 tonnes per 24 hours.

It operates on a cold top VERTICAL MELTING principle with HEXAGONAL melting area.

The system incorporates a single MELTING and REFINING chamber with a bottom entry THROAT and vertical RISER for connection to a DISTRIBUTOR and FOREHEARTH system.

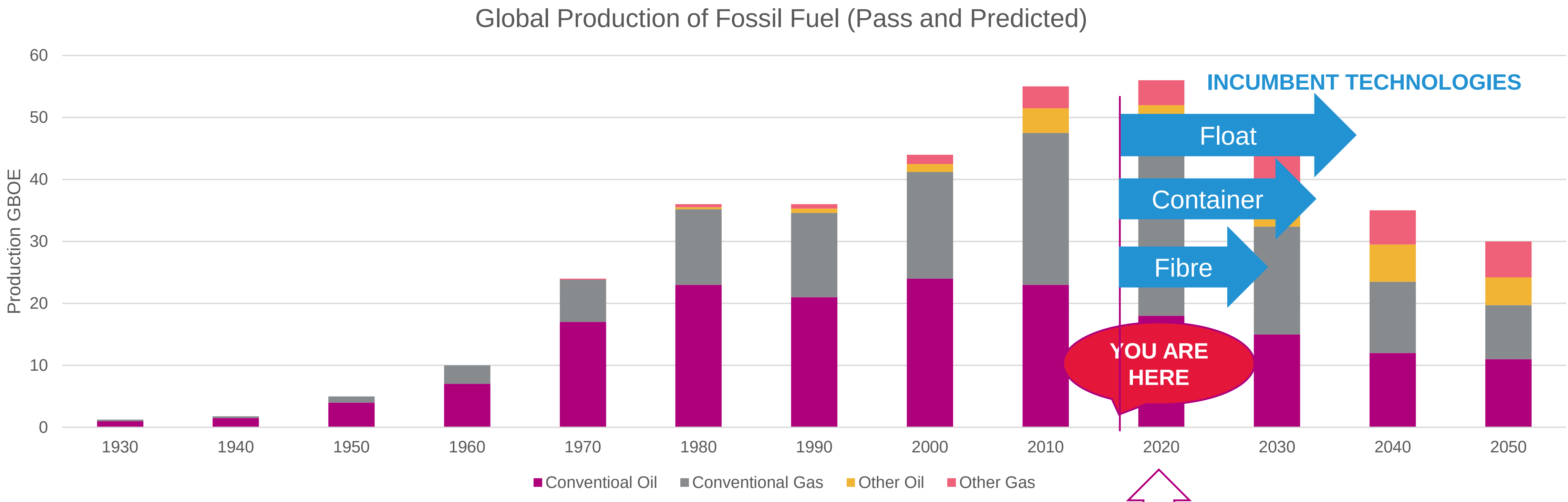
fives

All-electric Melting Technology

Electric Melting Today

All-electric Melting Technology

A time of uncertainty for fossil-fuel technology



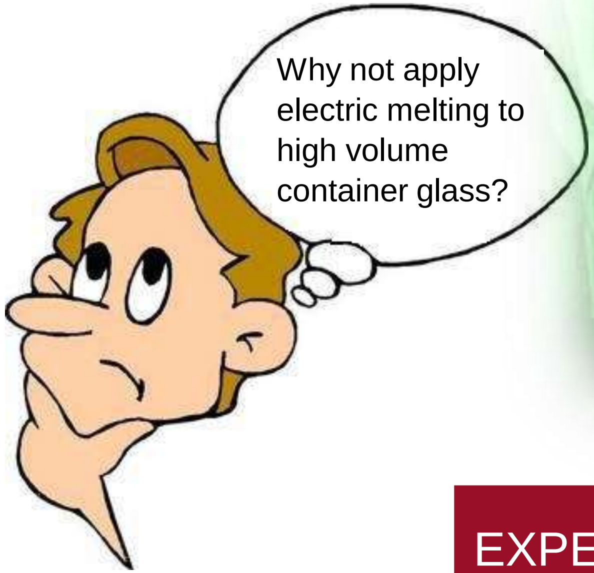
EU low carbon roadmap:
80% reduction in greenhouse gases by 2050 (from 1990 levels): Milestones to achieve this;
40% by 2030; 60% by 2040;
All sectors to contribute

2020 EU legislation to ensure climate/energy 3 targets:
20% reduction in greenhouse gases (from 1990 levels) 20% energy from renewables;
20% increase in efficiency

2030 EU legislation to ensure climate/energy 3 targets:
27% reduction in greenhouse gases (from 1990 levels) 27% energy from renewables;
27% increase in efficiency

All-electric Melting Technology

Application to Container Glass

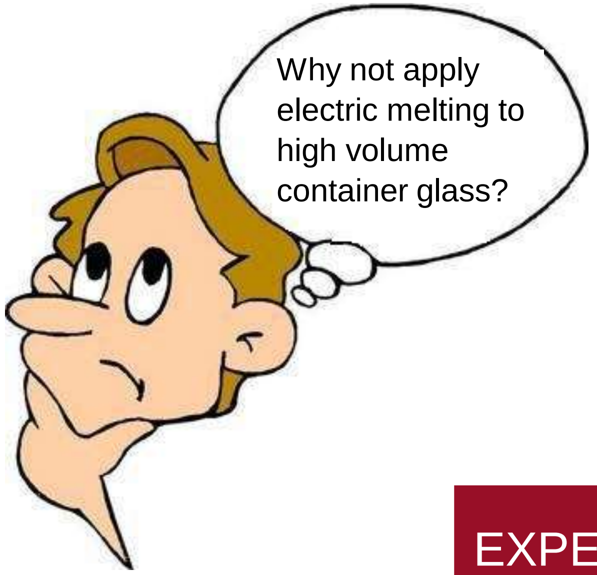


But...

- EXPENSIVE (High CAPEX and OPEX – high price of electricity)?
- SHORT CAMPAIGNS?
- LESS FLEXIBLE – OUTPUT/COMPOSITION?
- POOR STABLITY (INABILITY TO MELT REDUCED GLASSES)?

All-electric Melting Technology

Application to Container Glass



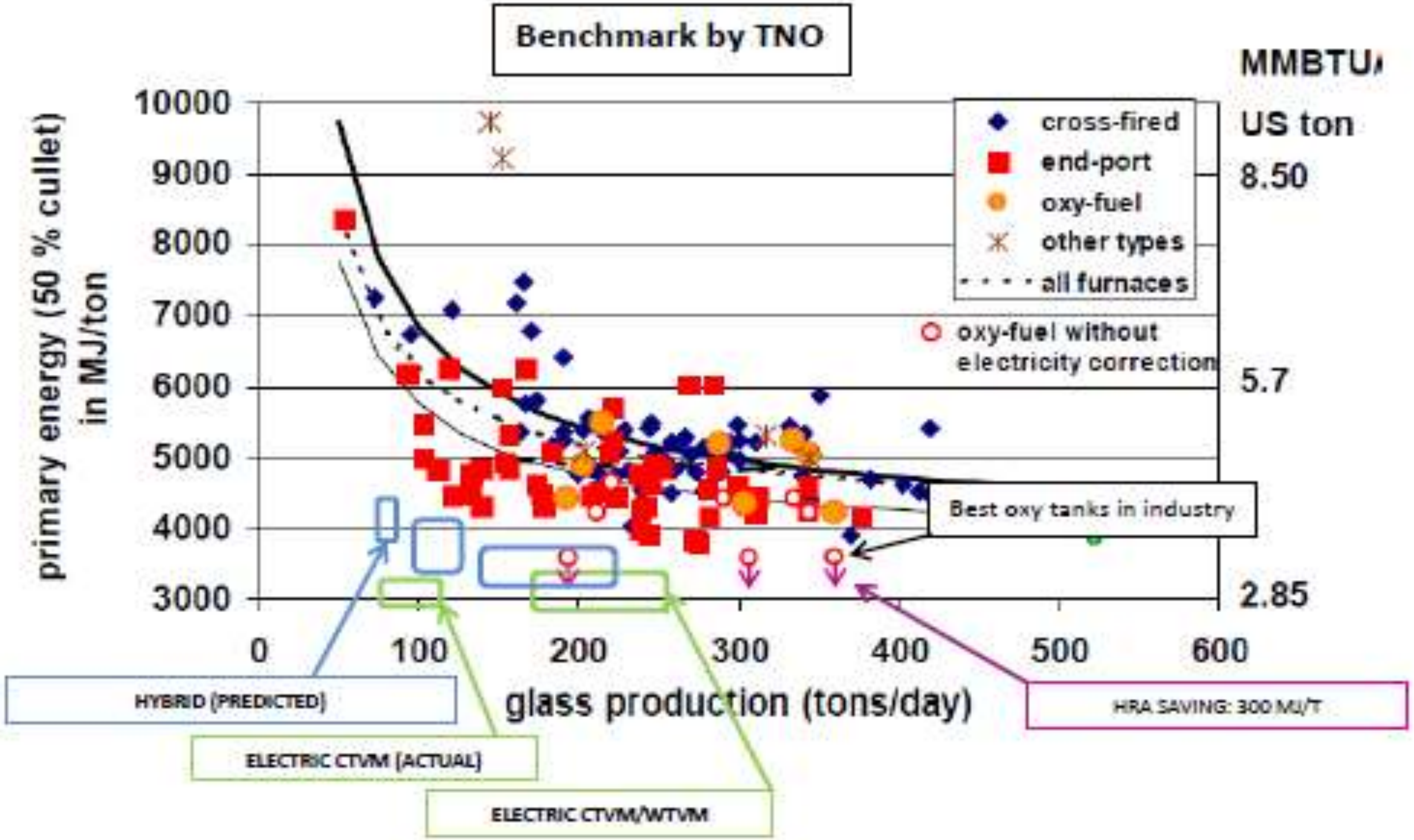
EXPENSIVE (High CAPEX and OPEX – high price of electricity)?

All-electric Melting Technology

Application to Container Glass

At 200TPD

- ❑ Best oxy-fired tanks get **~3.3 GJ/T**
- ❑ Best E-F Reg tanks get **~3.8-4.0 GJ/T**
- ❑ Cold-top all-electric can achieve **<2.75 GJ/T**



All-electric Melting Technology

Application to Container Glass

Assessing energy related operational costs on a general basis in quite challenging:

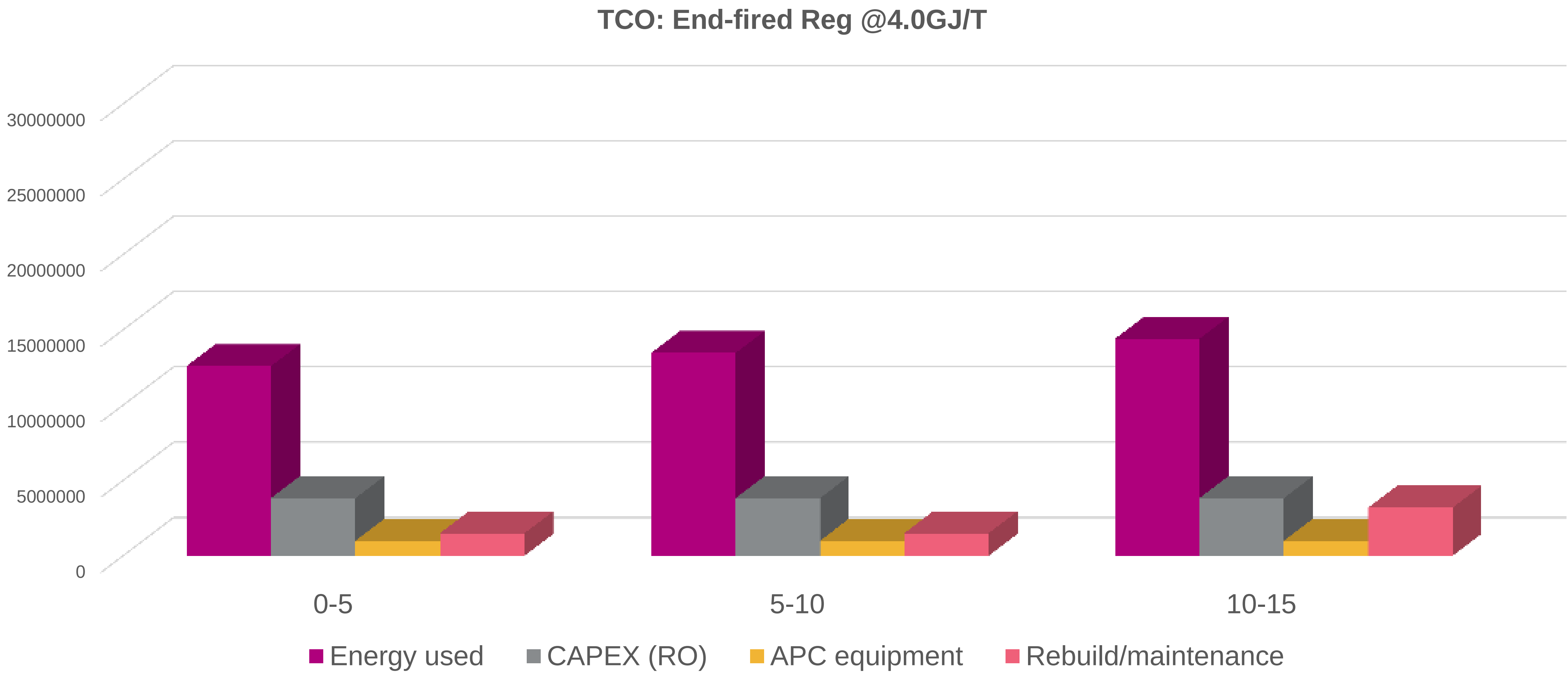
- Many different tariffs and (green) taxes
- Different pricing regimes in different regions, states and industrial sectors
- Prices dependent on consumption and level of security etc.
- Predicting how prices will change (and the relative price E/G) is difficult – many different models based of different assumption

For comparative purposed lets take:

- **Electricity:** **70 € MWh (inclusive of green taxes)**
- **Gas:** **30 € MWh**
- **C-tax** **18 €/T (CO_2)**

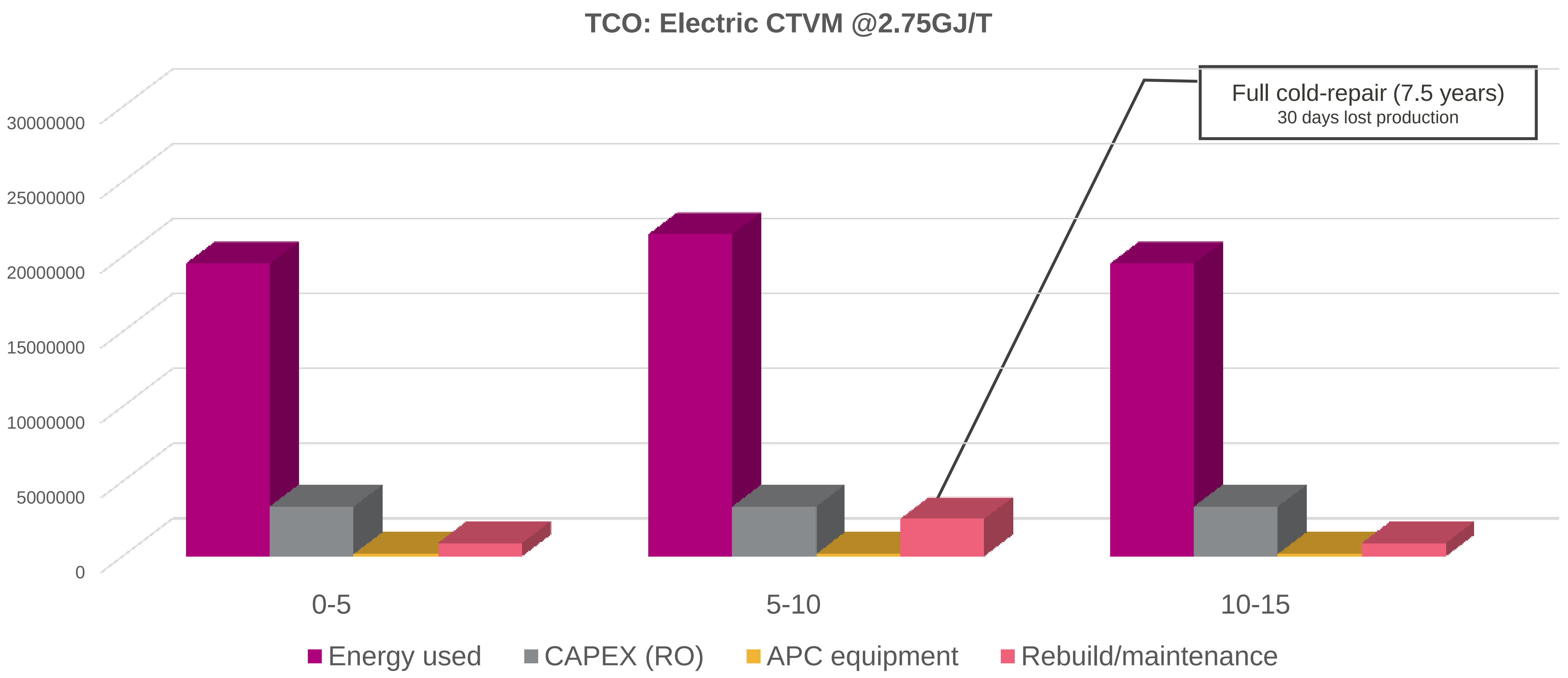
All-electric Melting Technology

Application to Container Glass



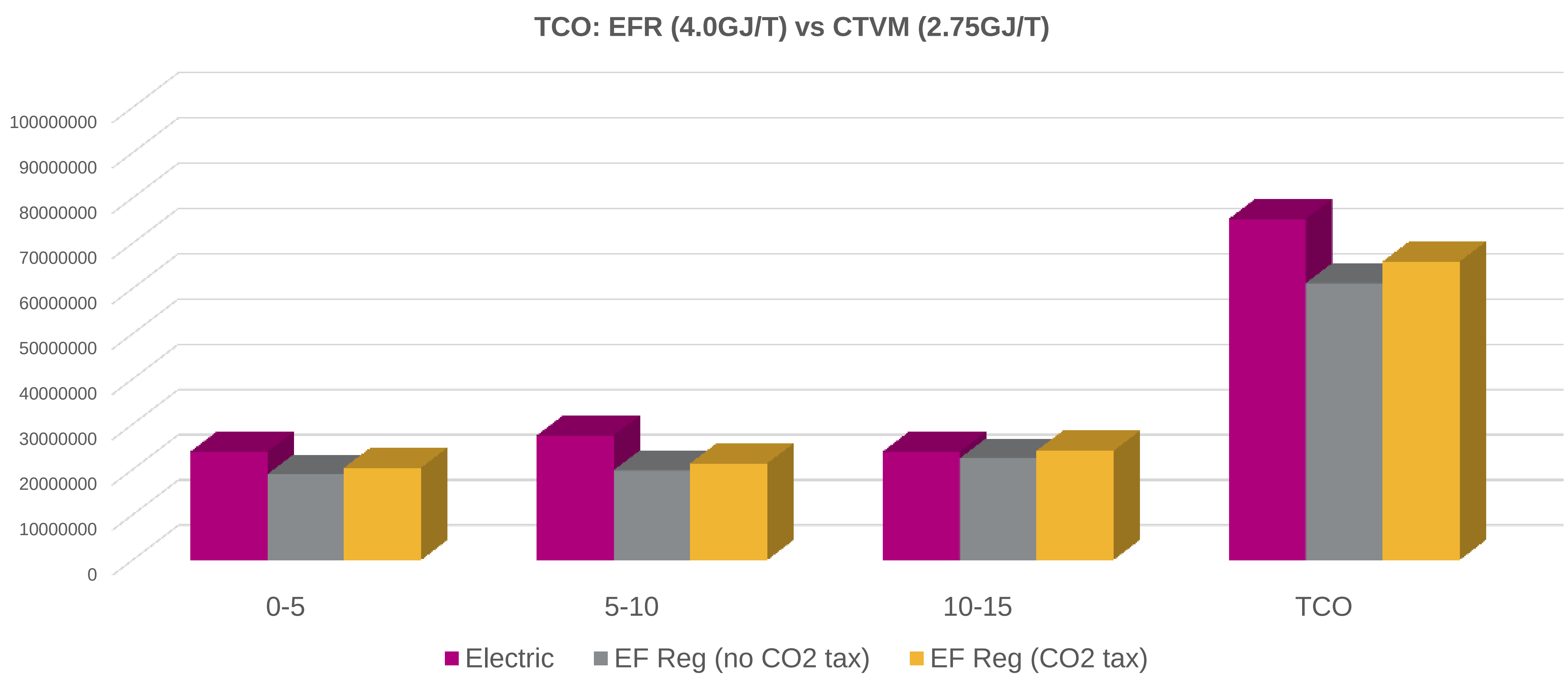
All-electric Melting Technology

Application to Container Glass



All-electric Melting Technology

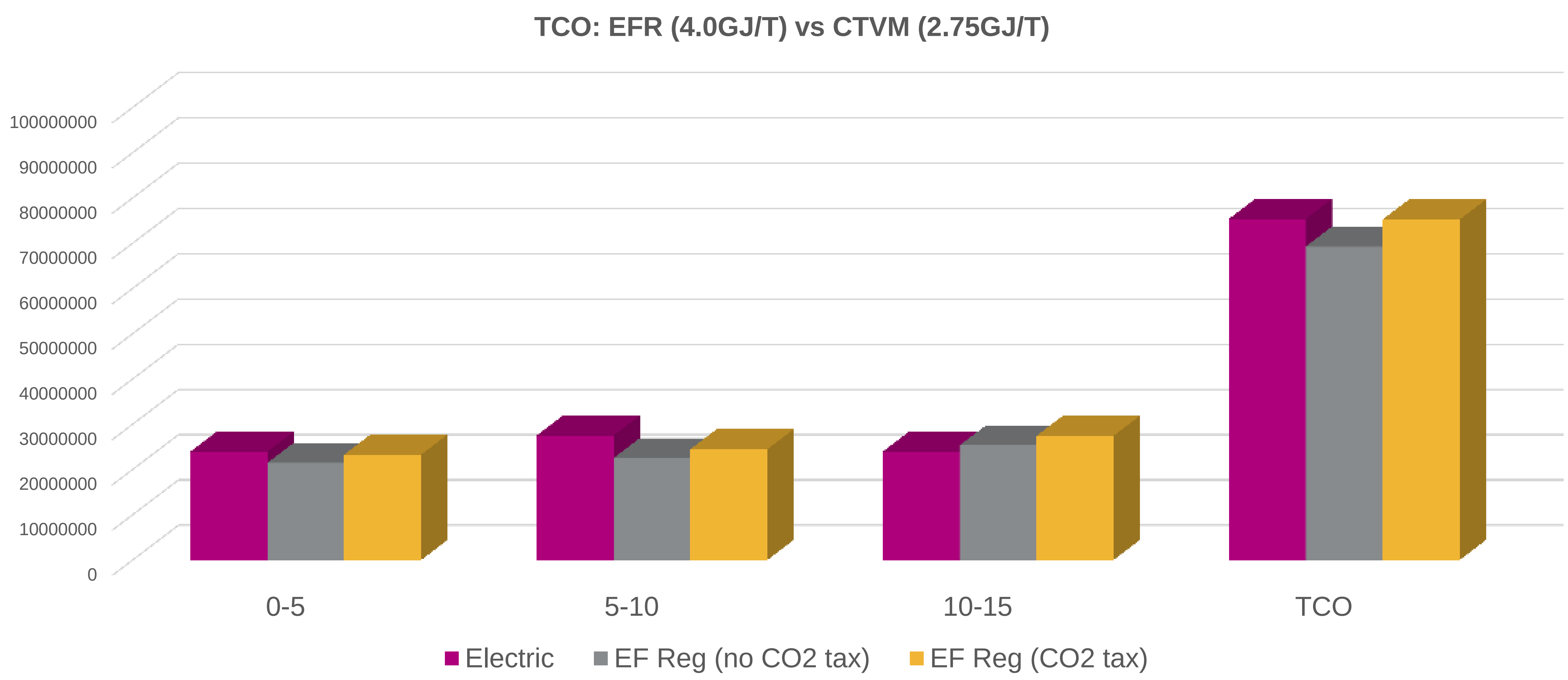
Application to Container Glass



Calculated using todays (typical) high-user energy tariffs (UK)

All-electric Melting Technology

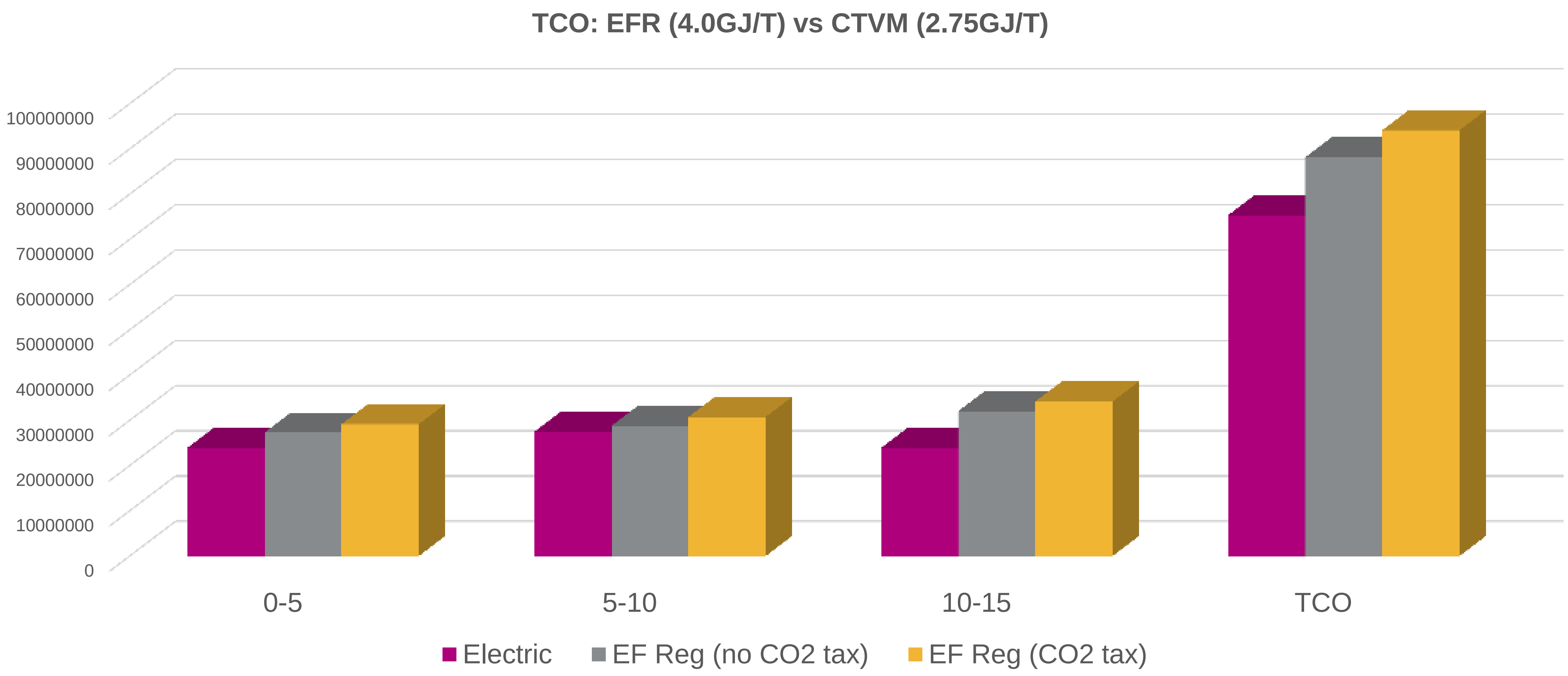
Application to Container Glass



Projected change in relative tariffs 5 years (mid-range prediction)
15% change on relative energy cost and 20% increase in C tax)

All-electric Melting Technology

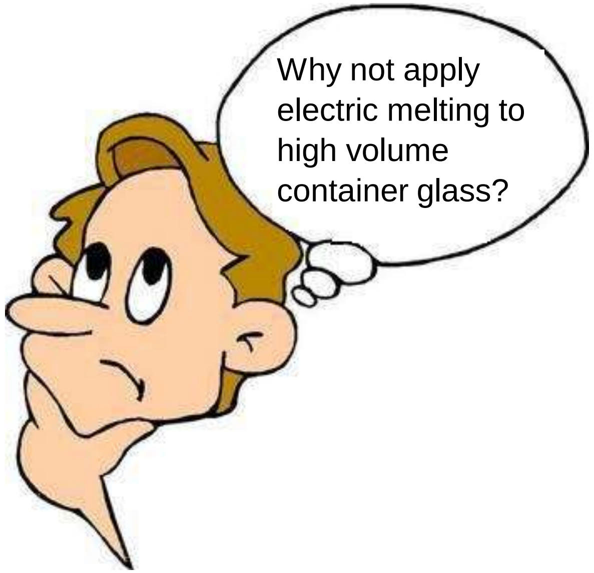
Application to Container Glass



Projected change in relative tariffs 10 years (mid-range prediction) 30% in relative energy costs 30% increase in C-tax

All-electric Melting Technology

Application to Container Glass



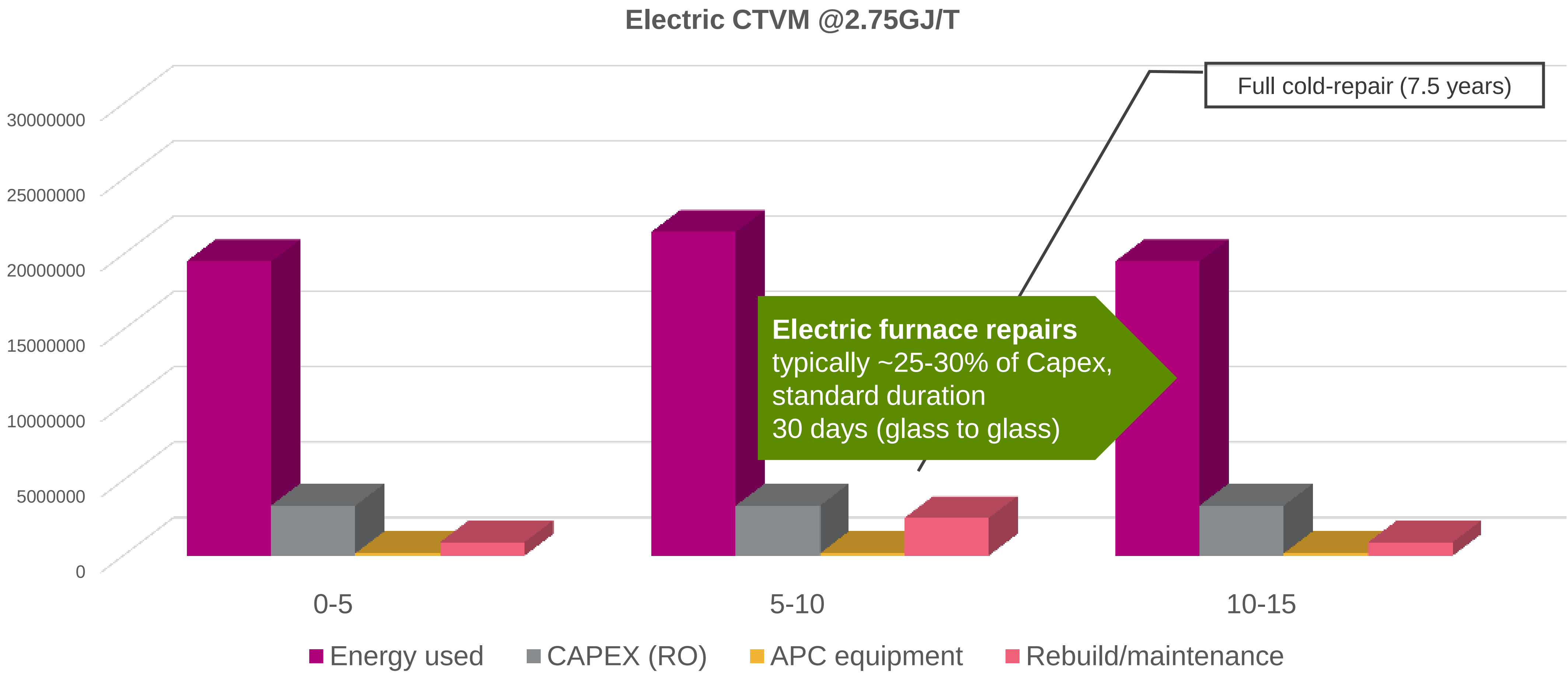
SHORT CAMPAIGNS?

Why are shorter campaigns necessarily a bad thing:
A rebuild is an opportunity to:

- Modify capacity (to take advantage of market conditions)
- Up-date technology (to optimise performance)
- Eliminate prolonged ‘end-of life’ maintenance issues

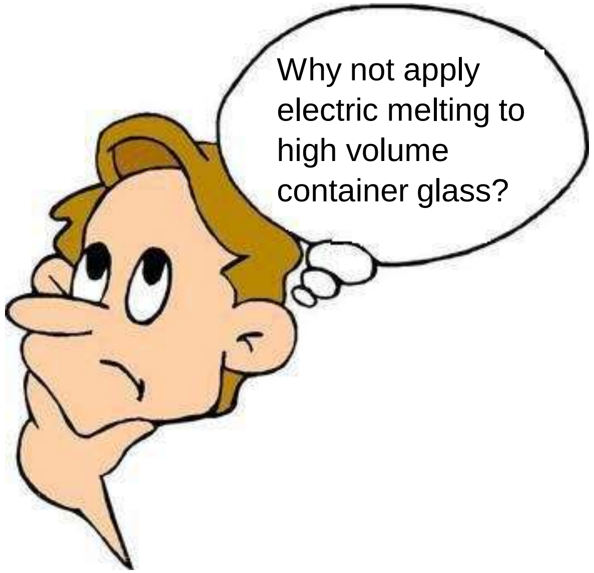
All-electric Melting Technology

Application to Container Glass



All-electric Melting Technology

Application to Container Glass



LESS FLEXIBLE – OUTPUT/COMPOSITION?

POOR STABLITY (INABILITY TO MELT REDUCED GLASSES)?

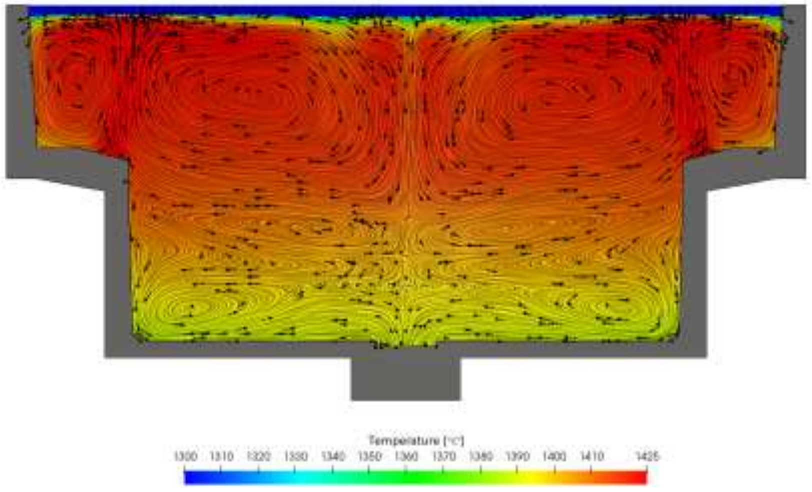
All-electric Melting Technology

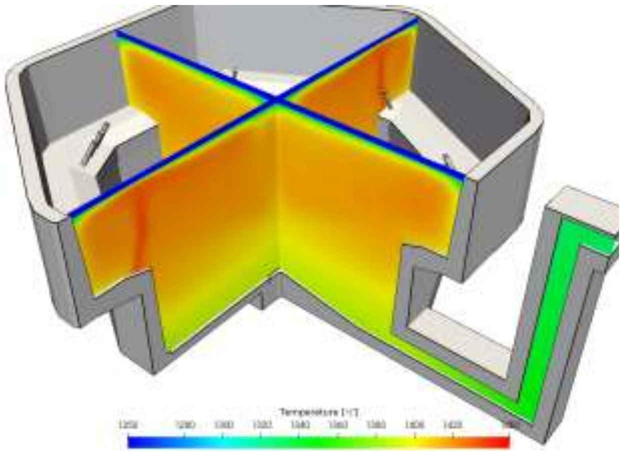
Flexibility & Stability of CTVM furnaces

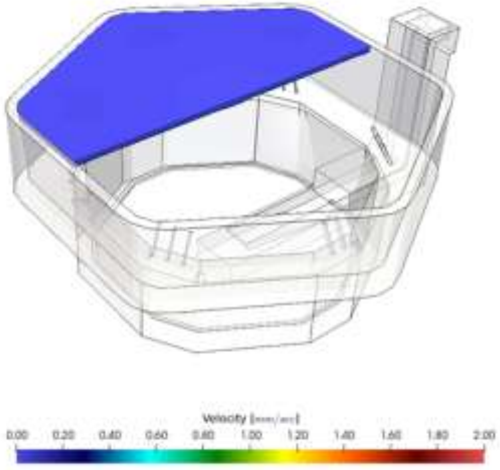
fives

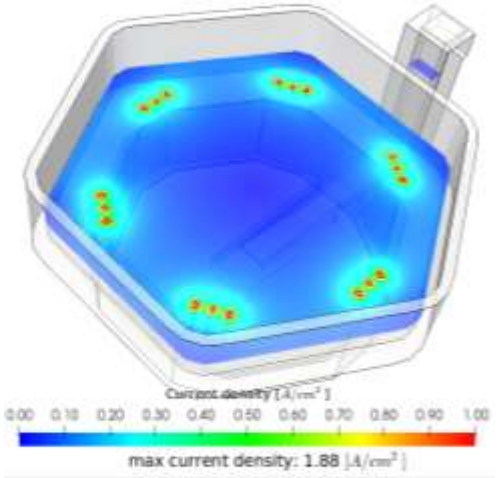
Our understanding of CTVMs have been progressed significantly in recent years through CFD modelling.

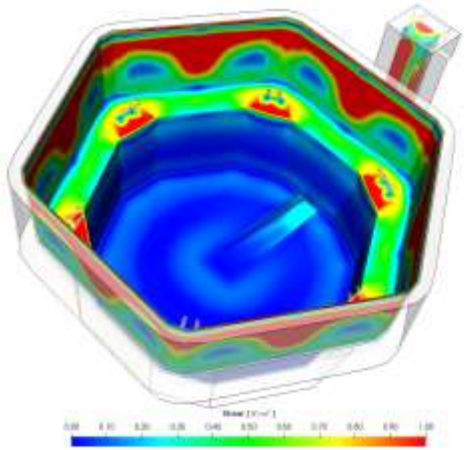
FSL modelling is now quite advanced. The fundamental principles and assumptions on which current models are based have been tuned and subsequently validated by extensive comparison against real furnaces; FSL works to improve and develop these models further. It is FSL policy on contracts any new design geometries should be validated through CFD analysis.









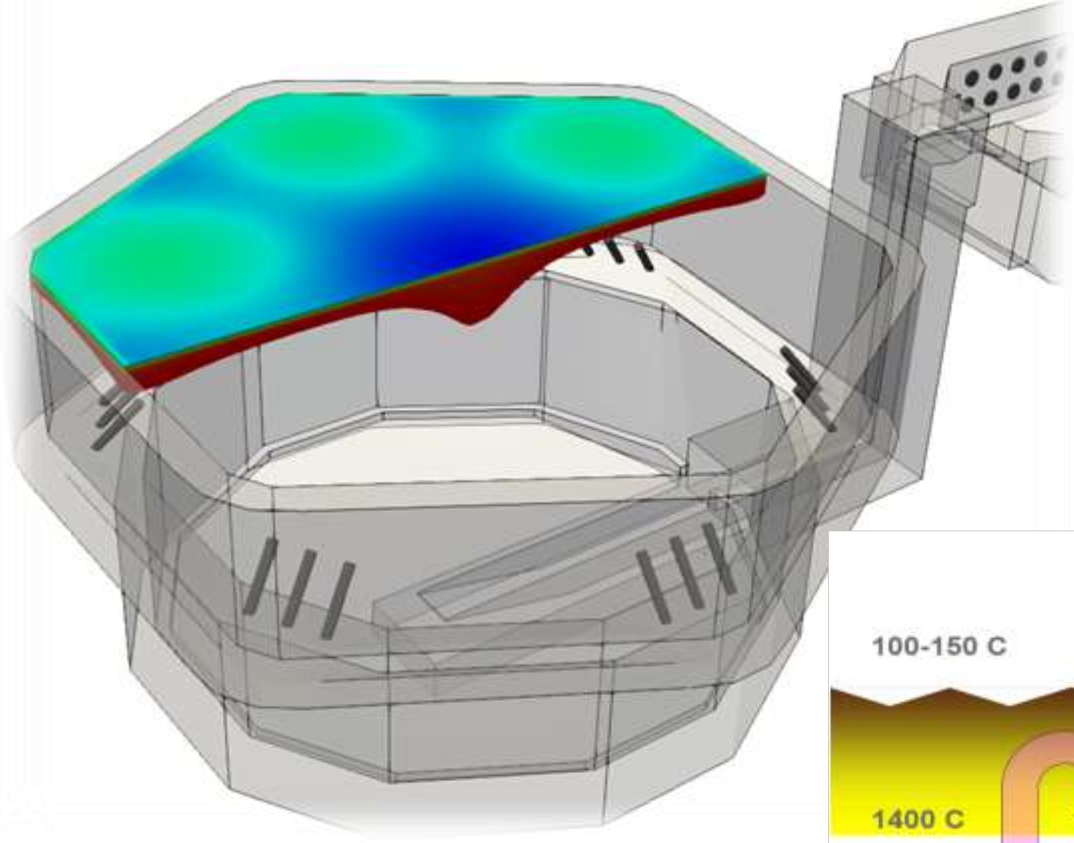


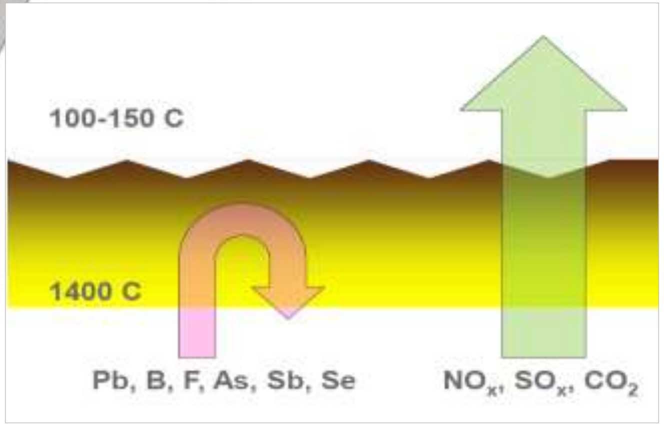
All-electric Melting Technology

Flexibility & Stability of CTVM furnaces

Furnace performance relies on maintaining a uniform and stable batch coverage: Furnace geometry and electrode positioning (and associated thermal/convection profiles), and batch charging technology has evolved to ensure a stable and uniform thickness can be maintained under a wide range of conditions

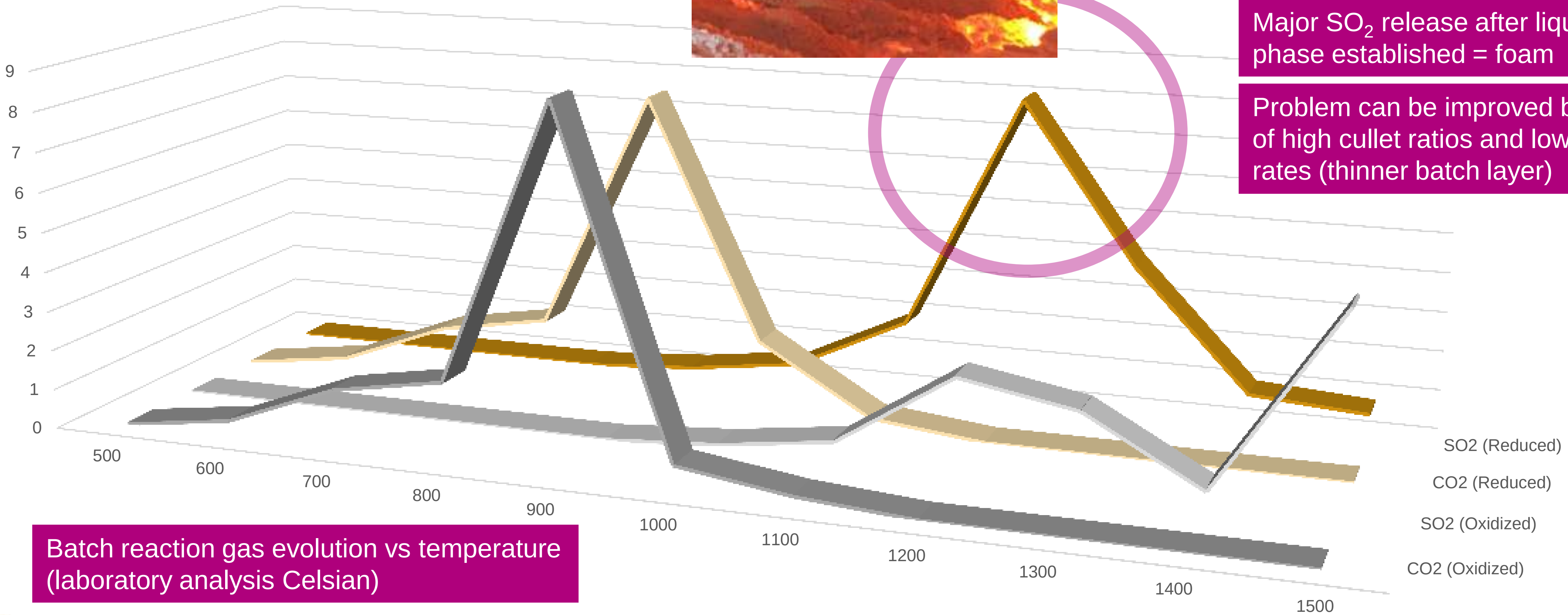
NOTE for reduced glasses (amber) it we need to consider gas evolution within the batch layer and this may impact melt rate.





All-electric Melting Technology

Flexibility & Stability of CTVM furnaces



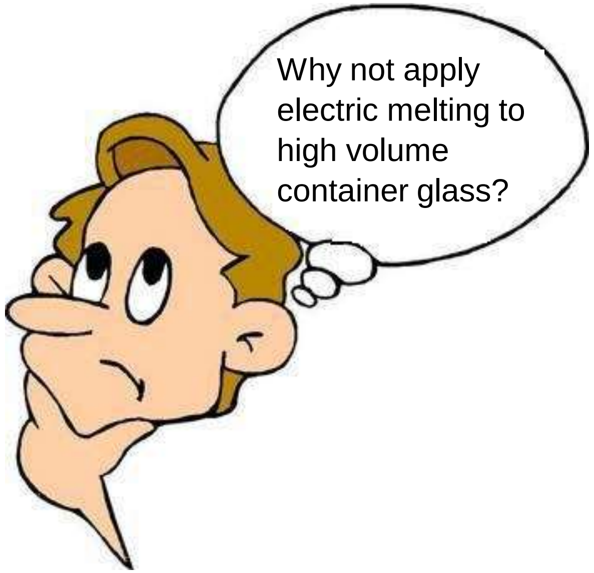
Major SO_2 release after liquid phase established = foam

Problem can be improved by use of high cullet ratios and low melt rates (thinner batch layer)

Batch reaction gas evolution vs temperature (laboratory analysis Celsian)

All-electric Melting Technology

Application to Container Glass



LESS FLEXIBLE – OUTPUT/COMPOSITION?

POOR STABLITY (INABILITY TO MELT REDUCED GLASSES)?

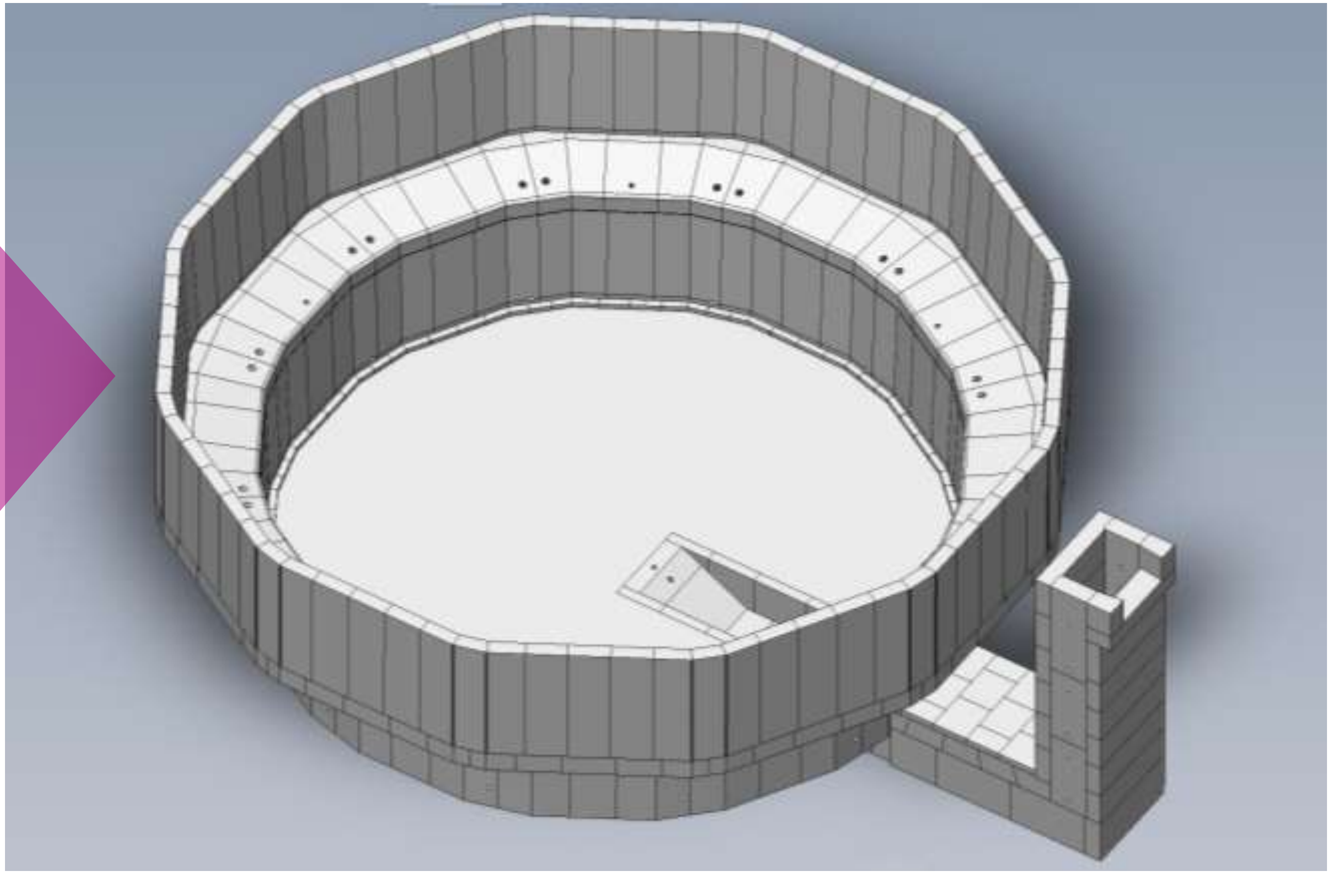
Today's CTVM furnaces

1. achieve operation to 50% of design load (without composition change)
2. 10-80% cullet range (with some output restrictions)
3. Stable operation with only one control parameter (kW)
4. Melting of reduced glasses can be realised with lowered melt-rates

All-electric Melting Technology

Application to Container Glass

?



CFD model of 100m^2 design concept

Can we extrapolate what we know from smaller units in order to design much larger systems. How can we reduce the risks…

All-electric Melting Technology

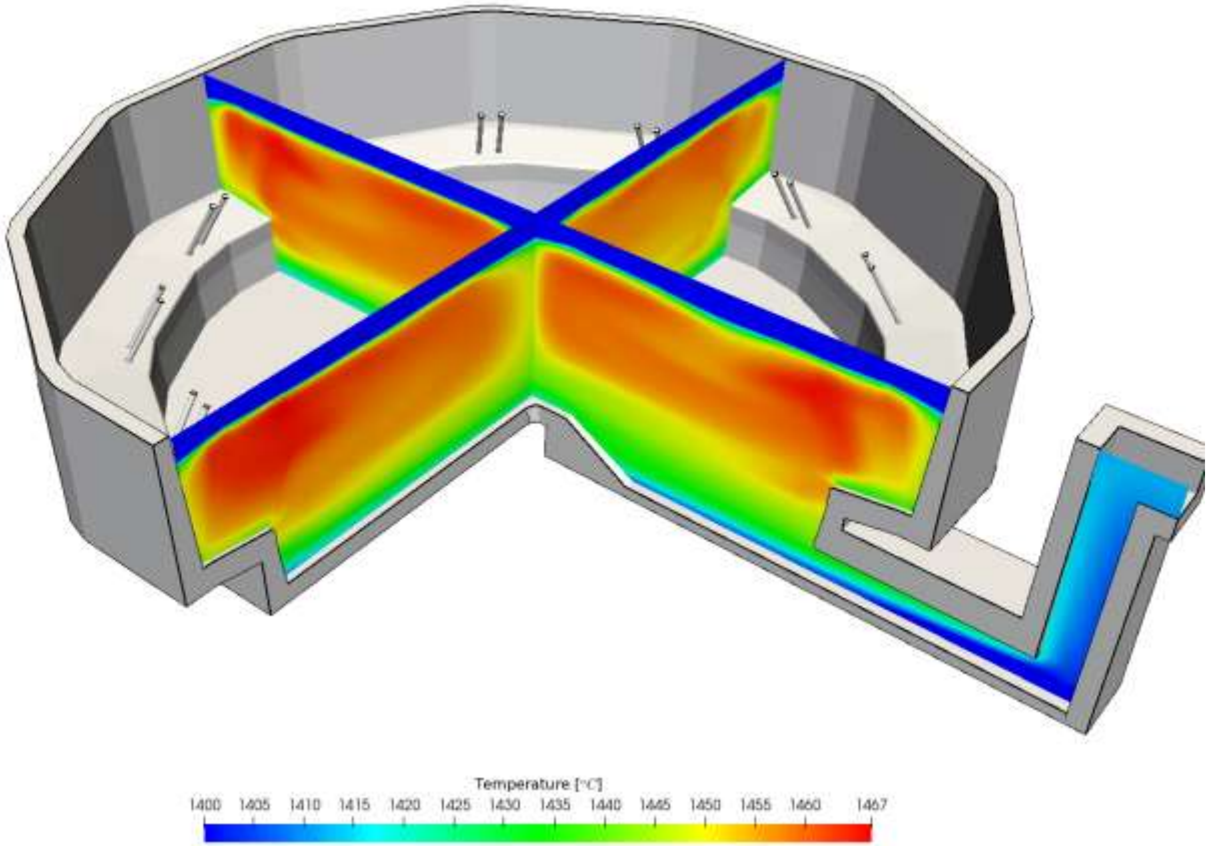
Application to Container Glass

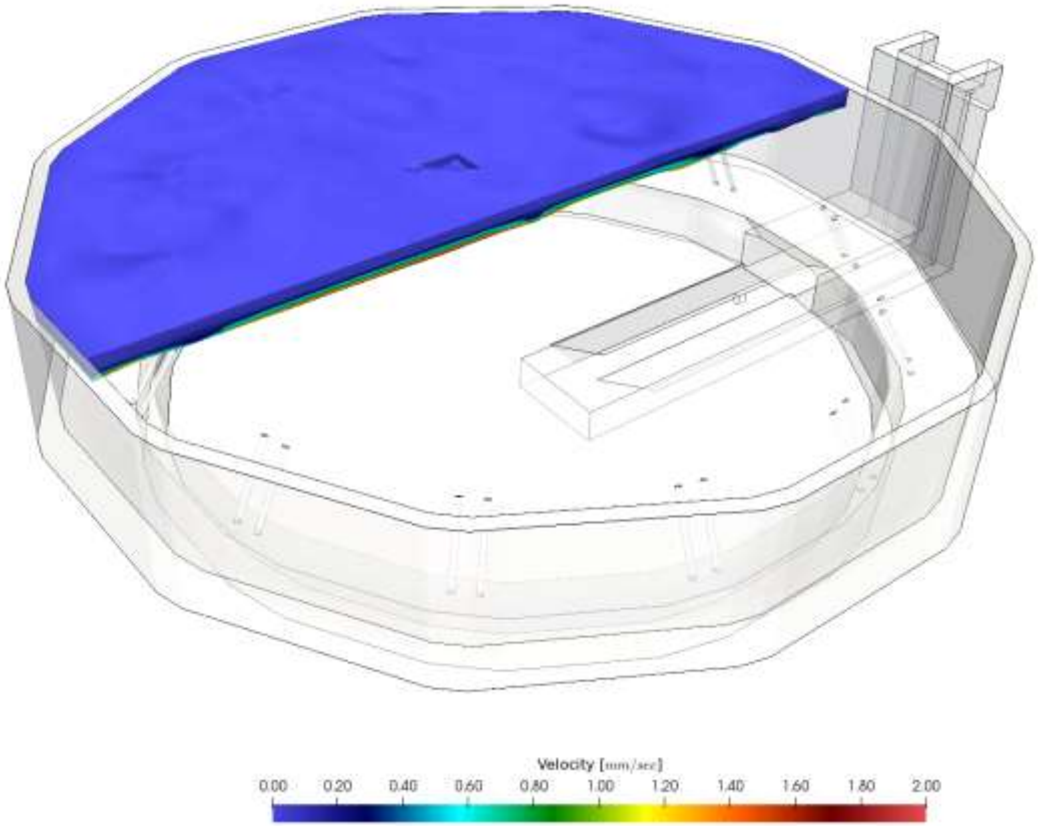
- Considerations for up-scaling CTVM technology
  - Melting
    - **Can we maintain a stable batch layer (cold-top) - e.g. foaming for reduced glasses**
    - **What range of melt rates can we achieve (at required cullet levels)?**
    - Consequence of differential melt rate (localised effect of electrodes)?
    - Can we achieve required thermal profile in the melt zone (under batch layer)?
    - Other considerations (e.g. volatiles, oxidizing agents in relation to Mo GME)
  - Fining/refining
    - Correct melting (do we reach required temperature)?
    - Can we ensure correct residence times (can we create thermal barrier)?
    - Can we achieve the required thermal drop for refining, is exit temperature workable?
    - **Do we achieve workable bottom and exit temperatures?**
  - Design
    - Power systems - how to up-scale and security issues?
    - Mechanical structure (how to manage deep furnaces?)
    - Batch feeding - how to accommodate large melt areas?
  - Operation
    - **Furnace control (can we achieve required stability and flexibility?)**
    - **Operation with high cullet % (can we deal with consequences of metal and/or redox control?)**
    - TOC (How to best manage the balance between life and energy efficiency?

The answers to these questions will change with glass type, quality requirements and production regimes. For example, the solution for container production will likely be very different from that for float glass.

All-electric Melting Technology

Application to Container Glass



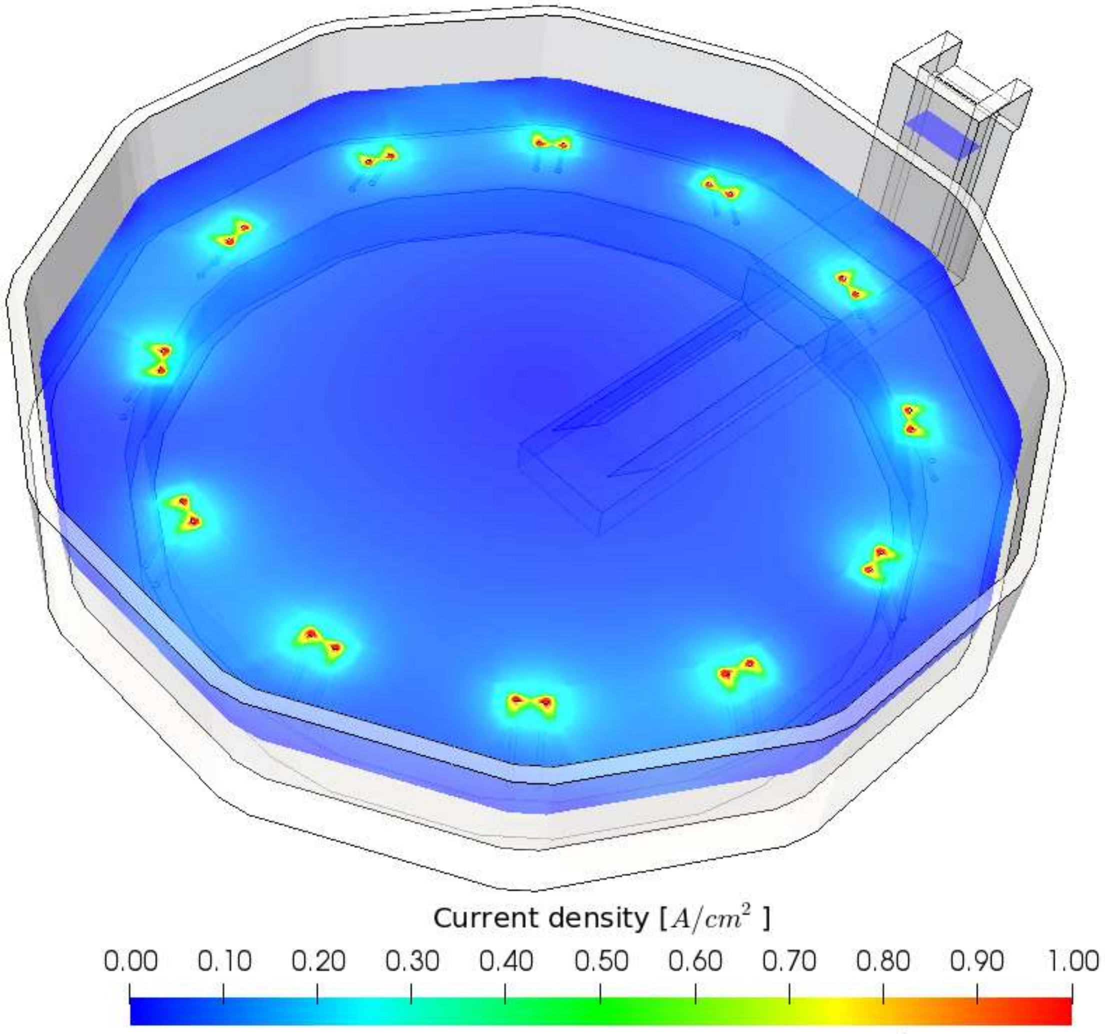


CFD model of 100m^2 design concept (applied to emerald green)

All-electric Melting Technology

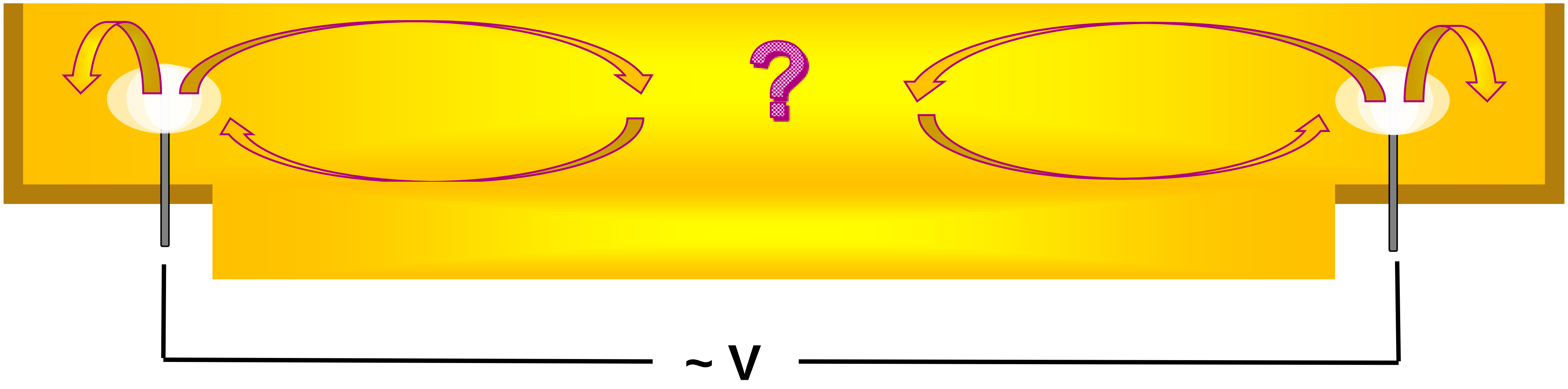
Application to Container Glass

The dodecahedron design can be accommodated by various electrode connection configurations; heating profile is similar to smaller furnaces.



All-electric Melting Technology

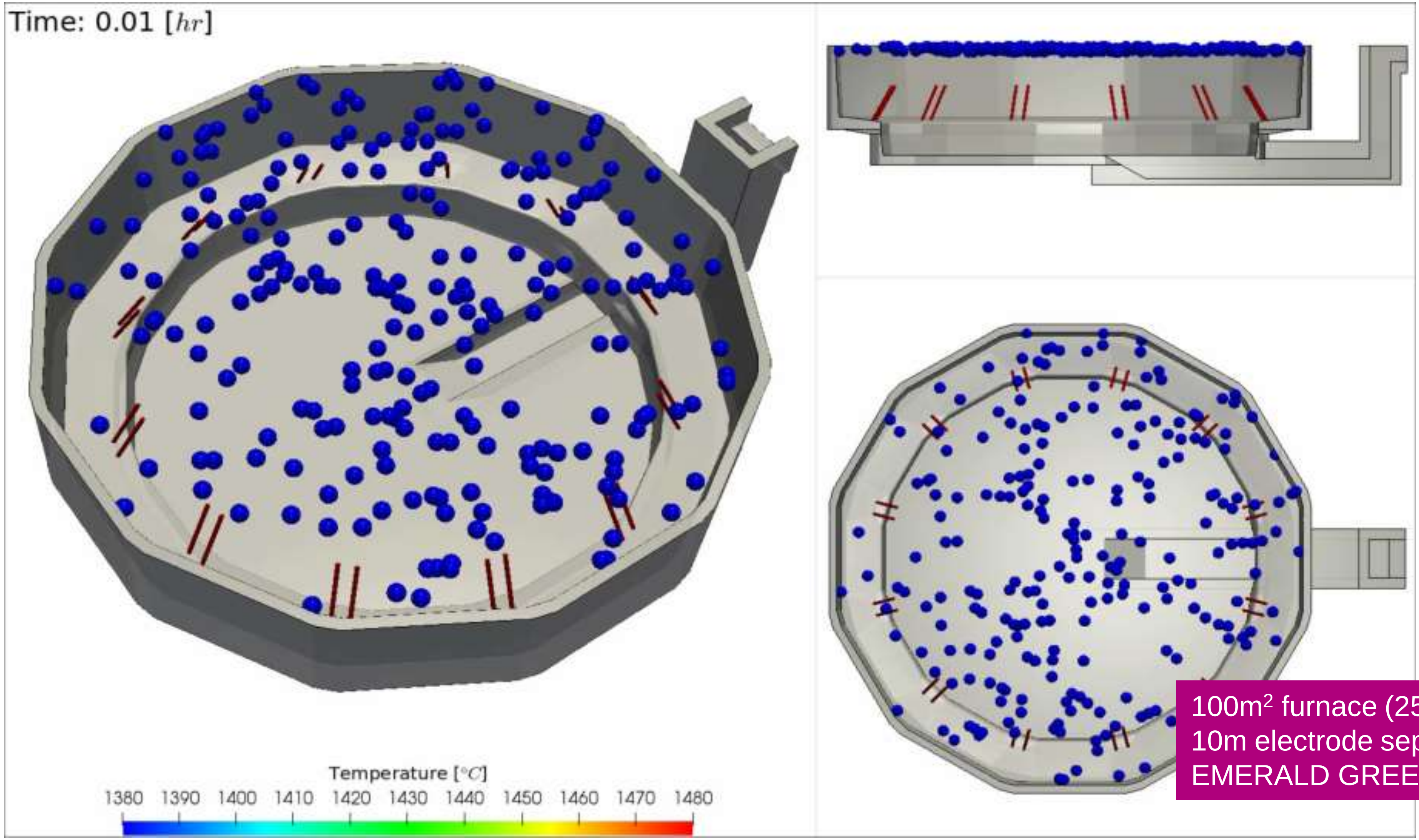
Application to Container Glass



What happens if the furnace gets much bigger and we move the electrodes further apart – do we still get similar convective profile, can we still maintain the correct thermal transfer

All-electric Melting Technology

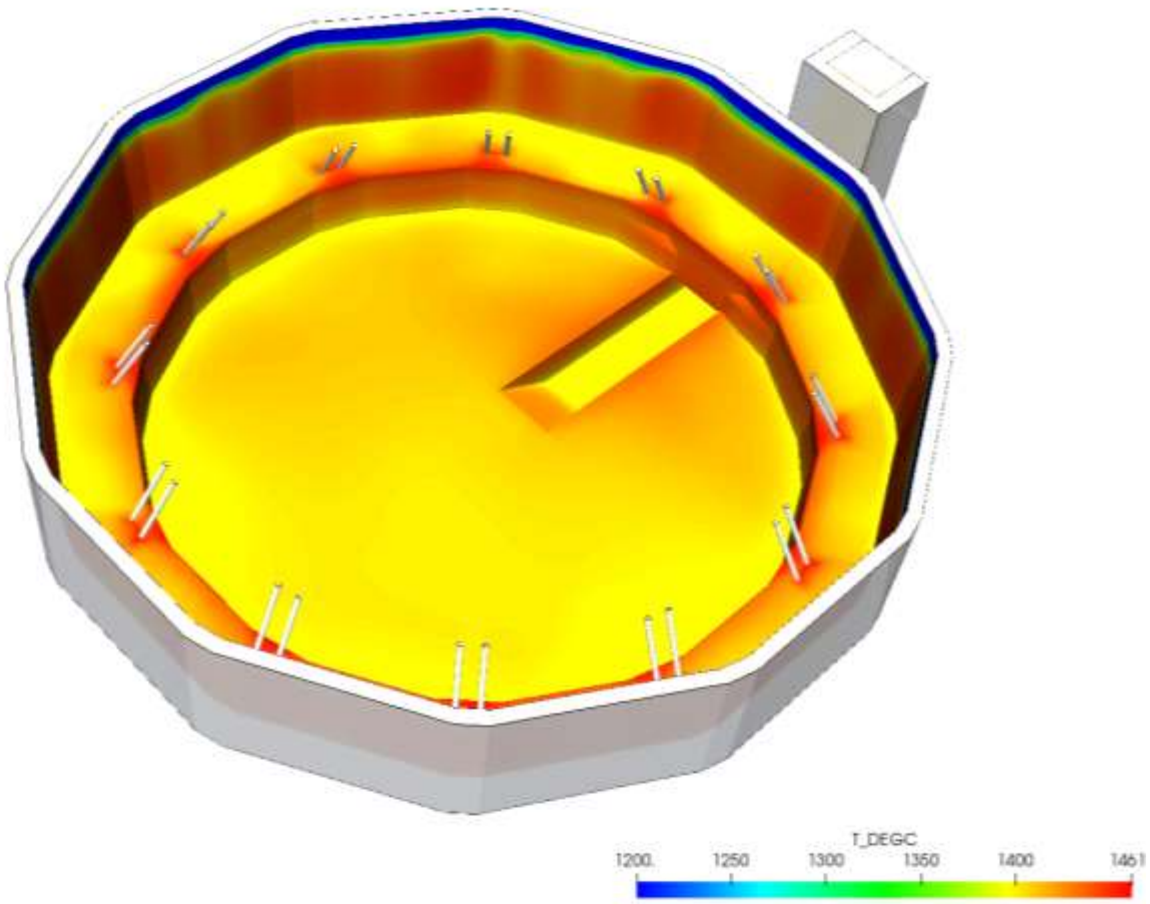
Application to Container Glass

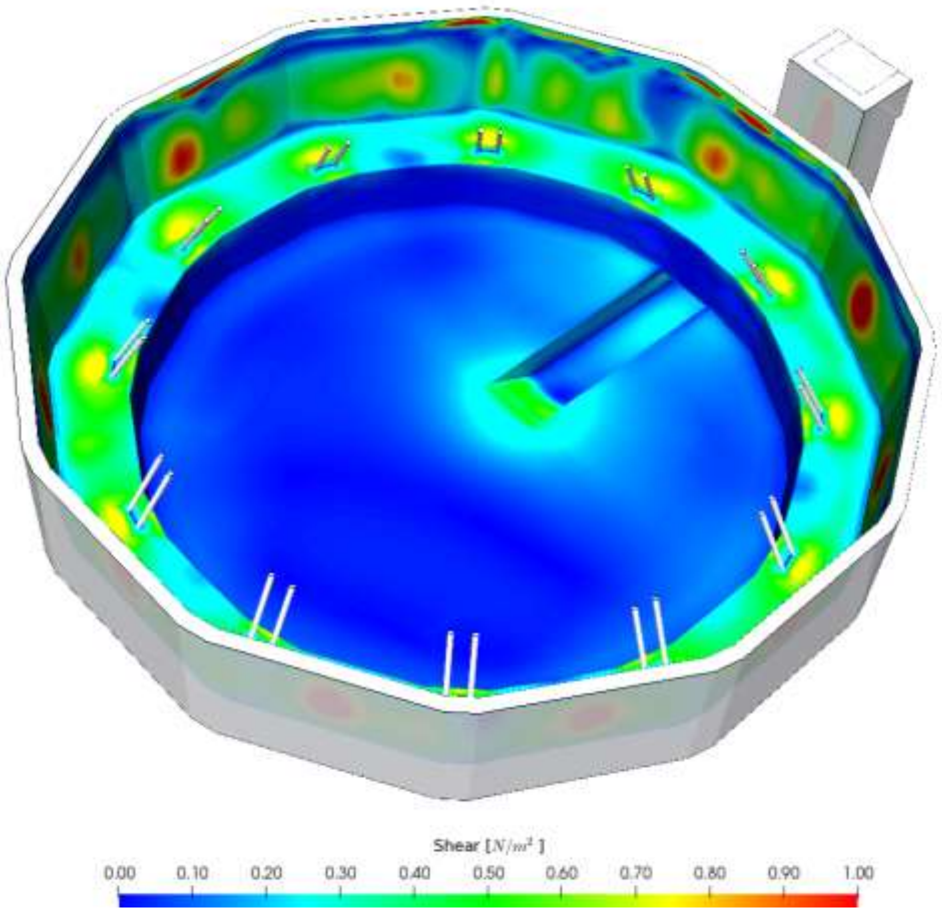


100m² furnace (250TPD)
10m electrode separation
EMERALD GREEN

All-electric Melting Technology

Application to Container Glass

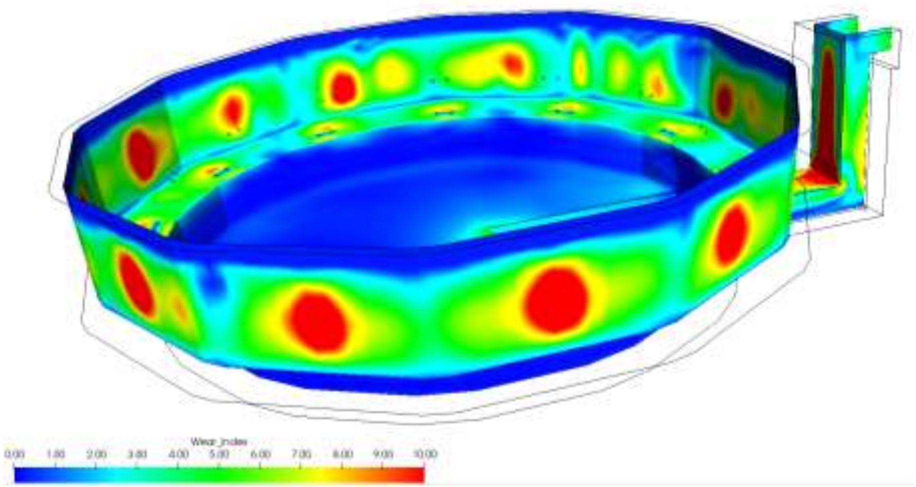


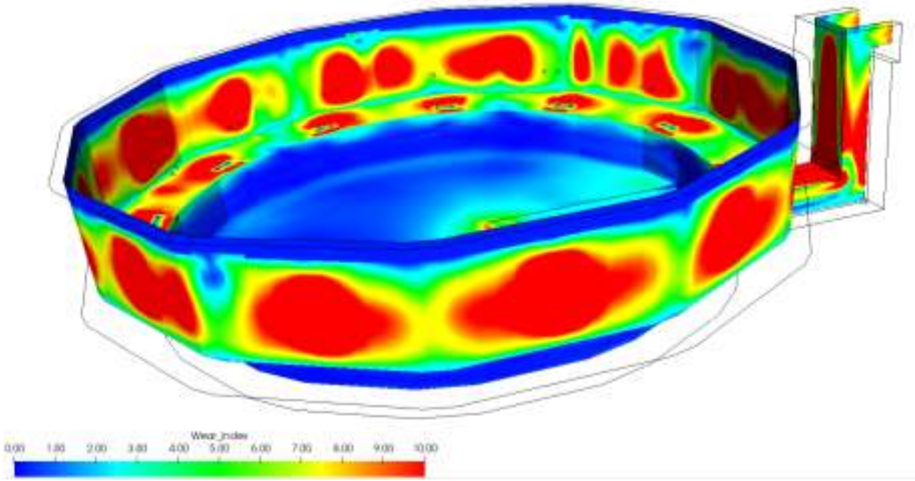


CFD modelling program includes prediction of refractory wear

All-electric Melting Technology

Application to Container Glass

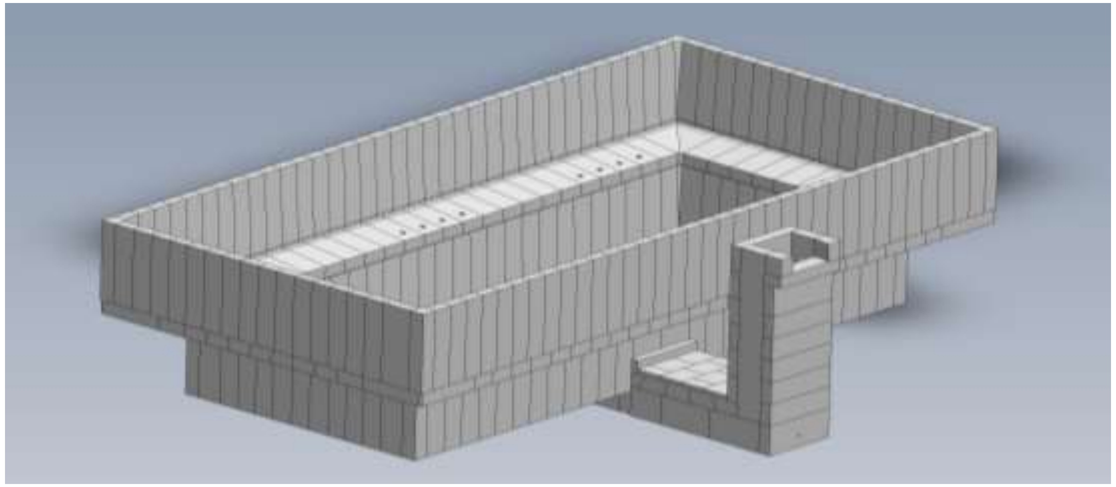


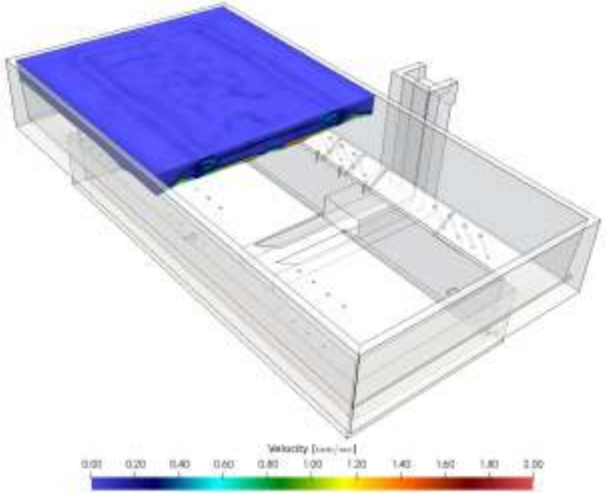


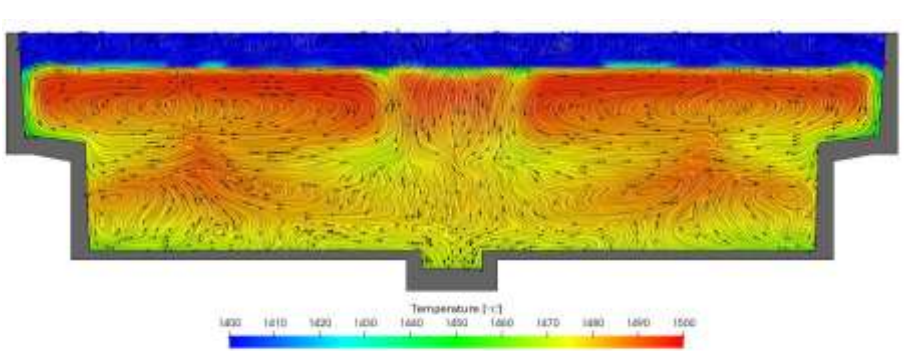
Wear index analysis can be used to design adaptive cooling systems

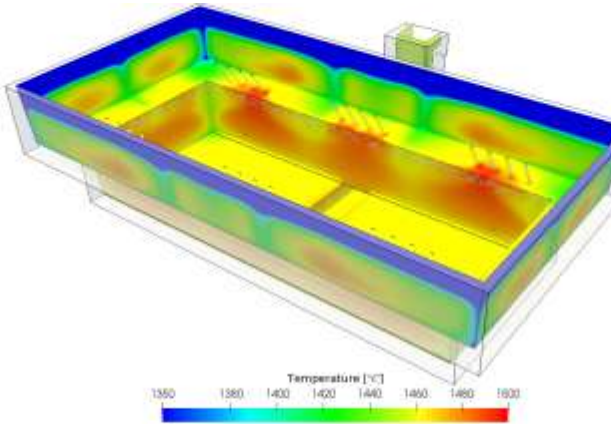
All-electric Melting Technology

Application to Container Glass









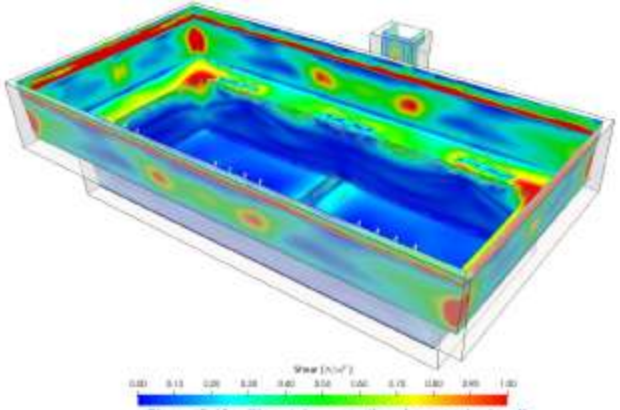


Figure 5-10 – Shear stress on the glass contact walls

All-electric Melting Technology

Application to Container Glass

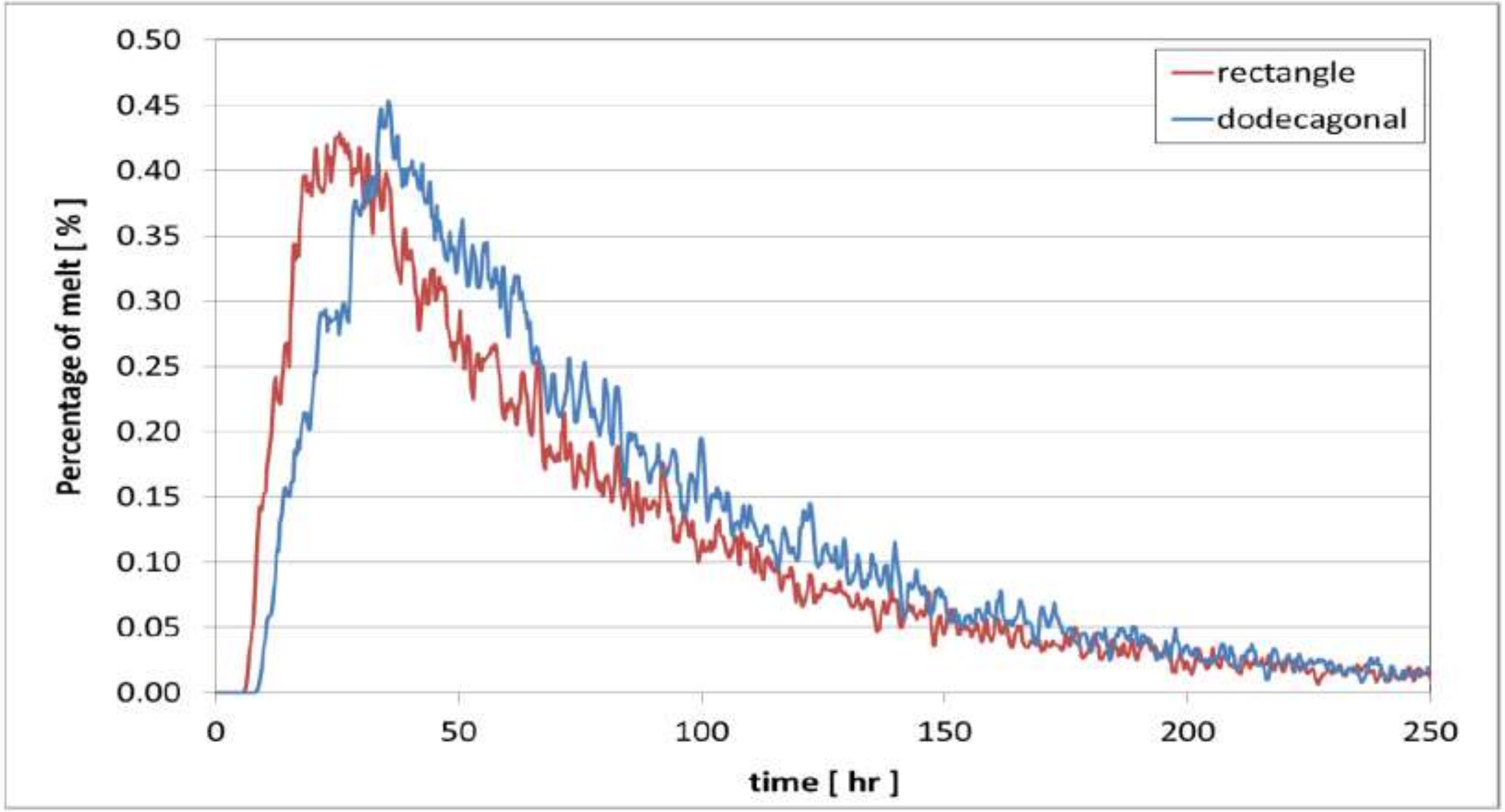
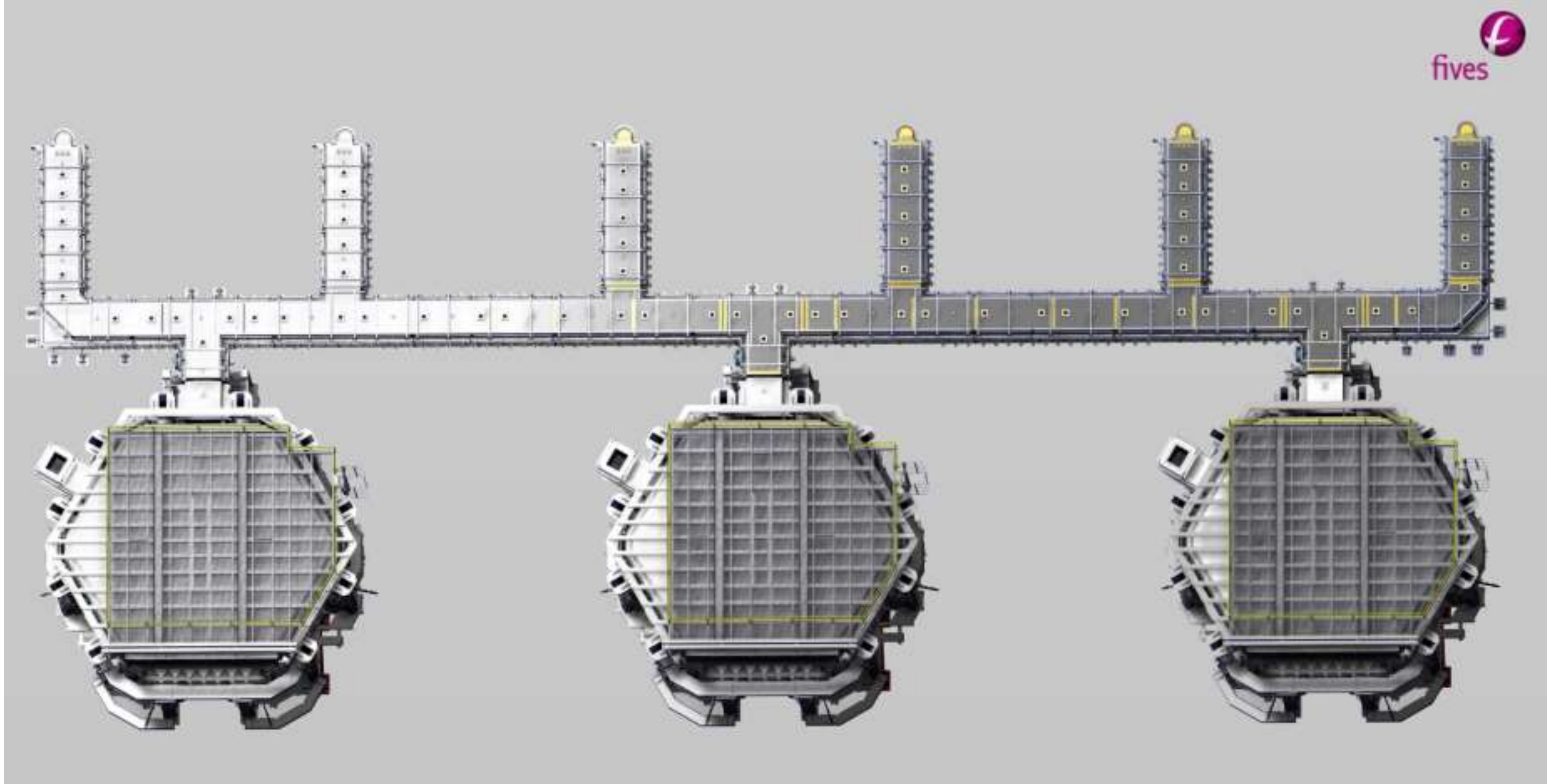


Figure 5.11 – Residence Time Distribution (RTD) of the glass.

All-electric Melting Technology

Application to Container Glass



❑ One solution is to use the modular approach… many merits….

Summary

- ENERGY EFFICIENT (already close to achieving TOC cost advantage)
- SHORTER CAMPAIGNS (opportunities to improve and upgrade)
- LIMITATIONS IN FLEXIBILITY CAN BE MANAGED
- EASE OF CONTROL (only one main control input – power)
- EASE OF MAINTENANCE (no heat recovery, APC, combustion etc.)

Andy Reynolds
Business Development Director
Fives Glass

andy.reynolds@fivesgroup.com
T +44 1235 517 226
M +44 7768 125 070

Fives Stein Limited
4CA Churchward,
Southmead Park, Didcot
OX11 7HB - UK